

## Cosmology in Portugal: The First 20 Years\*

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### Abstract

We reminisce on the first steps of the cosmology community in Portugal, which can be traced back to about 20 years ago, and discuss its achievements and current specificities. We also reflect on the aspirations, hopes and challenges for the future.

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# 1 Reminiscences

Cosmology is a relatively new science in Portugal. Its first steps can be traced back to about 20 years ago. This means that the development of cosmology as a research subject in Portugal has coincided with a particularly blooming period, a phase in which cosmology has evolved from its more speculative origins into a subject with highly predictive theories and precision measurements.

But, before we discuss the origins of cosmology in Portugal, we would better begin by paying a visit to the first discussions on relativity. Even though, in a passive way, Portugal has been related to the British expedition led by Arthur Eddington which was responsible for the measurement of the deflection of light in the 1919 eclipse. The measurements were carried out at Sobral, in the northeast region of Brazil, and at the Sundi area in Príncipe, then a Portuguese colony. That is to say, the confirmation of General Relativity occurred in two Portuguese speaking countries. In the case of the expedition to Brazil, there had been some participation of the Brazilian astronomers, and in what concerns the expedition to Príncipe, Eddington exchanged letters about logistics at the Sundi area with Campos Rodrigues and Frederico Oom, respectively, director and vice-director of the Observatório Astronómico de Lisboa [1, 2].

Actually, the first discussions about relativity in Portugal were of philosophical nature, and are due to Leonardo Coimbra (1883-1935) from the Faculdade de Letras da Universidade de Lisboa in 1912, on a dissertation about creationism. From then on, in the 1920s, the discussion was conducted predominantly by mathematicians, followed by a period of philosophical arguing and polemics about the interpretation of specific issues within relativity in the 1930s. The first lectures on Special and General Relativity in Portugal took place at the mathematics major at the Faculdade de Ciências da Universidade de Lisboa in the year 1922-1923, delivered by António dos Santos Lucas (1866-1939). The first research papers on Relativity, actually on differential geometry inspired by General Relativity and Unified Field Theory, are due to Aureliano Mira Fernandes (1884-1958) from Instituto Superior Técnico and appeared from 1928 till 1937 (at a rate of at least one per year) in the prestigious Italian journal *Rendiconti da Accademia dei Lincei*. This is a most remarkable and singular endeavour in the scenario of the Portuguese academic life at the time. Another important name at the time was Rui Luís Gomes, a disciple of Mira Fernandes who published in the *Rendiconti da Accademia dei Lincei* a paper about the Special Theory of Relativity

and created at the Faculdade de Ciências da Universidade do Porto, a theoretical physics seminar, which was the first organized attempt to set up, in a concerted fashion, theoretical physics in Portugal. In 1930, in order to fulfill the requirement of the examination for professorship at the University of Coimbra<sup>‡</sup>, Manuel dos Reis (1900 - 1992), an astronomer and mathematician, wrote an influential monograph, *O Problema da Gravitação Universal*, where gravity and relativity were discussed in an historical perspective [3]. During the academic year of 1930-1931, Mário Silva (1901-1977), who obtained a Ph.D. with Mme. Curie and was back to Coimbra in that year, declared his intention “to launch a discussion within the tiny Coimbra scientific community ... on some new doctrines such as the quantum and relativity theories” and which involved Manuel dos Reis. These discussions would lead to the first public confrontation between anti and pro-relativists in the country. The polemics took place in the journal *Seara Nova* (New Grain Field) and involved Mário Silva and Admiral Gago Coutinho<sup>§</sup>, who had heard Einstein lectures in Brazil in 1925 and attended the lectures of Paul Langevin in Lisbon in late 1929, but could not accept or understand some of the kinematic implications of Special Relativity. Other pro-relativistic texts appeared in the cultural journal *O Diabo* (The Devil) by Abel Salazar<sup>¶</sup> [3]. Influential textbooks on electromagnetism and special relativity appeared in the second half of the 1940s by Mário Silva [4] from Coimbra and António da Silveira (1904-1985) [5] from Instituto Superior Técnico. From the 1940 to the 1960s, the central figure in relativity and cosmology in Portugal was António Gião from the Faculdade de Ciências da Universidade de Lisboa and Instituto Gulbenkian de Ciências. Gião has exchanged letters with Einstein, published papers on relativity and cosmology in the Physical Review [6, 7] and organized a NATO cosmology meeting in 1963, which had among the participants, Pascual Jordan, Yves Thiry, Hermann Bondi and others [8]. To this scarce, but regular interest in relativity, followed a quiet period till the *Revolução dos Cravos* in 25th of April 1974, when a military coup restored democracy in Portugal after almost 50 years of dictatorship. Since then, the universities and the academic life have undergone profound transformations. The university

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<sup>‡</sup>The University of Coimbra is the oldest in the country. It was established through a decree by King Dom Dinis and confirmed by the pope Nicolau IV in 9 of August of 1290.

<sup>§</sup>Admiral Gago Coutinho (1869-1959) and the airman Artur de Sacadura Cabral (1880-1924), were the first men to cross the South Atlantic in a non-stop flight from Lisbon to Rio de Janeiro in 1922.

<sup>¶</sup>Abel Salazar (1889-1946) was a physician, scientist, author and artist who lived in Porto and was an influential figure in the Portuguese cultural life from 1920s onward.

population has, since then, grown about eight-fold and academic standards have improved considerably, despite the still rather limited resources<sup>||</sup>. Interest in relativity has awakened again in the mid 1970s and a course on General Relativity was then delivered by the French physicist Maurice Bazin based on the textbook of which he is a co-author [9] at the Faculdade de Ciências da Universidade de Lisboa. Subsequently, courses were delivered in the same faculty by António Brotas from Instituto Superior Técnico in late 1970s [10]. The first course on Relativity, which included also Cosmology was delivered by Paulo Crawford do Nascimento in autumn/winter semester of 1983 in the physics course in the Faculdade de Ciências da Universidade de Lisboa. In Instituto Superior Técnico, the first Relativity and Cosmology course was held by this author to students of the Physics and Mathematics Departments in the spring/summer semester of 1993. About the same time, cosmology lectures started being held by Paulo Gali Macedo at the Universidade do Porto. Since then, lectures on General Relativity and Cosmology have been regularly held in these three universities, both at undergraduate and graduate levels.

The first papers on cosmology were written in Portugal about 20 years ago. The first ones were solo flights by Alfredo Barbosa Henriques concerning higher dimensional cosmological models [11], by Estelita Vaz on Bianchi-type spaces [12] and a more mathematical work by Maria Helena Bugalho, Amaro Rica da Silva and José Sousa Ramos on chaos on a Bianchi-IX cosmological model [13]. Three papers appeared in the following year, another one by Alfredo Barbosa Henriques in collaboration with Gordon Moorhouse [14], a paper by Paulo Crawford Nascimento in collaboration with Rubem Mondaini on anisotropic universes and inflation [15] and a paper by Maria Helena Bugalho on cosmologies with a non-Abelian two-parameter isometry group [16]. In this period, research activities were carried out at the Instituto de Física e Matemática, now Complexo Multidisciplinar da Universidade de Lisboa at Avenida Gama Pinto, 2, a multidisciplinary and multi-university research institute which encompassed researchers in atomic and nuclear physics, condensed matter physics, field theory, particle physics and mathematics, from the three Lisbon universities: Universidade de Lisboa, Universidade Técnica de Lisboa and Universidade Nova de Lisboa. The institute existed since the 1960s and was founded by António da Silveira, funded initially by the Instituto da Alta Cultura, a government financing

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<sup>||</sup>Even at present, the fraction of the GNP allocated to research and development does not exceed about 0.8%, one of the lowest of the European Union.

institution of cultural and scientific activities, and later on by the Instituto Nacional de Investigação Científica (INIC), a national research foundation which existed till 1992. By the late 1980s and early 1990s, there was a convergence of people coming from abroad with a wide range of interests including cosmology. The mathematical physicist Roger Picken had been in the institute since 1987. This author did arrive from a post-doctoral experience in Heidelberg to work at the Instituto de Física e Matemática in October 1989 with a post-doctoral fellowship from Grupo Teórico de Altas Energias; José Mourão arrived in 1990 after completing his Ph. D. studies in Moscow and so did Maria da Conceição Bento, who came from a post-doctoral period at London. The four of us were in the early 1990s hired as lecturers at Instituto Superior Técnico at the Mathematics and Physics Departments. Together with two young Ph. D. students, Paulo Moniz and Paulo Sá and a M. Sc. student, Luís Mendes, it was possible to organize a weekly seminar in cosmology, to build a preprint library and to create an environment where various problems of cosmology could be tackled and discussed. These included, for instance, solutions of the Einstein-Yang-Mills system (classical [17], wormhole-like [18] and quantum cosmological [19]), Kantowski-Sachs cosmological models [20], Bianchi IX models [21], symmetry breaking in curved spacetime [22] and string cosmology [23]. By 1993, José Pedro Mimoso [24] was back to Faculdade de Ciências of the Universidade de Lisboa after completing his Ph. D. in Sussex.

The other major center of activity in cosmology in Portugal is Porto where the first papers to appear were on bounds for the Jordan-Thiry scalar field coupling constant by Paulo Gali Macedo [25], on the Sunyaev-Zeldovich effect and its cosmological implications [26] in 1996 by Domingos Barbosa and co-authors, on cosmic strings [27] in 1997 by Pedro Avelino and co-authors and, on galaxy cluster abundance and cosmological parameters [28] in 1999 by Pedro Viana and Andrew Liddle. More recently, Carlos Herdeiro and Miguel Costa and Carlos Martins have joined the group and enriched the list of research subjects to include Gödel type universes [29], string cosmology [30] and cosmic strings [31] to mention just a few.

The other groups, although smaller, are no less relevant. The group at Universidade do Minho, got established in the early 1980s after Estelita Vaz came back from her Ph. D. in Britain; José Castanheira da Costa joined her a few years later and went to the Universidade da Madeira in the 1990s. The group at the Universidade do Algarve was established in the early 1990s by Cenalo Vaz and Robertus Potting

[32], the former now gone to the US, and Paulo Sá joined the group in 1995 [33]. The group at the Universidade da Beira Interior was established by Paulo Moniz in the late 1990s [34] and José Velhinho joined him in 2000 [35].

## 2 Current Trends

Currently, research in cosmology in Portugal is carried out in 6 out of the 14 state Universities\*\*. They are the following, where we indicate within parenthesis the name of the researchers:

Universidade do Algarve at Faro (Paulo Sá and Robertus Potting)

Universidade da Beira Interior at Covilhã (Paulo Moniz and José Velhinho)

Universidade de Évora (Ilídio Lopes)

Faculdade de Ciências da Universidade de Lisboa (Luis Bento, Paulo Crawford, Tom Girard and José Pedro Mimoso and Ana Nunes)

Instituto Superior Técnico of the Universidade Técnica de Lisboa (Maria da Conceição Bento, Orfeu Bertolami, Alfredo Barbosa Henriques and Ana Mourão)

Universidade do Minho at Braga and Guimarães (Filipe Mena, Piedade Ramos and Estelita Vaz)

Faculdade de Ciências da Universidade do Porto (Pedro Avelino, Miguel Costa, Paulo Carvalho, Carlos Herdeiro, Catarina Lobo, Paulo Gali Macedo, Fátima Mota, Caroline Santos and Pedro Viana)

Quite often, the research is developed in Physics Departments, but also at Applied Math Departments in the case of the Universidade do Porto and Universidade do Minho. However, formally, and this is a well marked feature of science activities in Portugal, research activities take place in the context of research centers which are related with the universities, but have some administrative independence and some freedom to guide research interests and their development. Cosmology is a research topic in 8 centers. Their spread within the above mentioned universities is as follows:

Faculdade de Ciências da Universidade de Lisboa:

Centro de Astronomia e Astrofísica da Universidade de Lisboa (CAAUL)

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\*\*The public sector also comprises about 20 polytechnic institutions.

Centro de Física Nuclear (CFN)  
Centro de Física Teórica e Computacional (CFTC).

Instituto Superior Técnico (IST):  
Centro Multidisciplinar de Astrofísica (CENTRA)  
Centro de Física dos Plasmas (CFPI)  
Centro de Física Teórica e Partículas (CFTP).

Faculdade de Ciências da Universidade do Porto:  
Centro de Astrofísica da Universidade de Porto (CAUP)  
Centro de Física do Porto (CFP).

Besides the above mentioned researchers, an important feature of the Portuguese scientific community working in cosmology is that it is relatively young and that a great deal of activity is carried out by young researchers, post-docs and Ph.D. students. There are about 18 post-docs and their distribution around the country is as follows: 1 in Braga-Guimarães, 1 in Faro, 12 in Lisbon, 4 in Porto and there are 6 Portuguese post-docs abroad (indicated with \*), some willing to come back within a period of 1 to 3 years. Let me name them:

Tiago Barreiro, Domingos Barbosa, Jarle Brinchmann, Simone Calogero, Carla Carvalho, Patricia Castro, Tiago Charters, Morgan Le Delliou, Vikram Duvvuri, Sébastien Fabbro, Pedro C. Ferreira, Francisco Lobo, Carlos Martins, Luis Mendes\*, David Mota\*, Rui Neves, Nelson Nunes\*, Jorge Páramos, Mário Santos, Nuno Santos\*, António Silva, Pedro Silva, Ricardo Schiappa\*, Luis Teodoro\*.

There are also about 14 Ph. D. students: 1 in Braga-Guimarães, 1 in Faro, 5 in Lisbon and 7 in Porto. Let me name them:

Vladan Arsenivejic, Luis Beça, Catarina Bastos, Irene Brito, Luís Costa, Rosa Doran, João Fernandes, Josinaldo Menezes, Joana Oliveira, Carmen Rebelo, Ismael Tereno, Brigitte Tomé, Paulo Torres, Pedro Vieira.

Currently, the research in cosmology in Portugal covers the major areas of interest, which includes quantum cosmology, strings and brane cosmology, inflation, cosmic microwave background radiation, cosmic strings, cosmological phase transitions and cosmology in the laboratory, dark matter, dark energy, variation of fundamental couplings, spacetime symmetries and topology and observational cosmology.

In many of these subjects, papers written in Portugal have reached a position of

visibility, having more than 50 and 100 citations according to the QSPIRES database. Among those, one could mention, for instance, papers on baryogenesis [40], cosmological and astrophysical aspects of the of Lorentz symmetry breaking [41, 42], dark energy [43, 44, 45, 46, 47], inflation [48] and the variation of fundamental constants [49, 50, 51]. Papers on Lorentz symmetry breaking and gravity [52] and on dark energy [53] have been awarded 3rd Prizes by the Gravity Research Foundation in U.S., in 1999 and 2005. A paper on dark matter has been awarded the Prize União Latina de Ciência in 2001 [54].

It is quite exciting that this quality recognition can also be found in papers on observational cosmology and data analysis, such as, for instance, on the Sunyaev-Zeldovich effect and its implications for cosmology [55], on constraints on the matter power spectrum normalization using SDSS/RASS and reflex cluster survey [56] and on supernova survey and cosmological parameters [57]. It is also quite remarkable the Portuguese involvement on the team that has identified the oldest cluster ever observed, with  $z = 1.45$ , in the context of the XMM cluster survey [58].

These papers indicate that, recently, there has been a serious involvement of the Portuguese cosmology community on observational activities. The most salient are the following:

Galactic Emission Mapping (Building a radio telescope for studying the foreground of the galactic synchrotron emission) (CENTRA)

Planck Surveyor (CENTRA-Working Group 7, CAUP-Working Group 5)

Square Kilometer Array (CENTRA)

Supernova Cosmology Project and Supernova Legacy Survey (CENTRA)

XMM-Newton Cluster Survey (CAUP)

Pioneer Anomaly and LATOR (Laser Astrometric Test of Relativity) Science Teams (CFPI)

We can also mention the involvement of the community on recent publications aiming to raise the public awareness on cosmology and, in particular, on the work

developed in Portugal:

*Descobrir o Universo*, Teresa Lago *et al.* (Ed. Gradiva, April 2006).

*O Livro das Escolhas Cósmicas*, Orfeu Bertolami (Ed. Gradiva, January 2006).

To these books, we can add the chapter on cosmology written by José Pedro Mimoso which appeared in the book *O Código Secreto* (Ed. Gradiva) by Margarida Telo da Gama *et al.* in 2005.

Portugal has been also the stage of many international conferences on cosmology. Indeed, since the 1990s, conferences have been taken place in Portugal on a regular basis. The most attended include:

XII Autumn Lisbon School: The Physical Universe, Lisbon, October 1990.

Orgs. J. Barrow, A. B. Henriques, M. T. V. Lago and M.S. Longair [36]

Iberian Meeting on Gravity, Évora, September 1992.

Orgs. M. C. Bento, O. Bertolami, A. B. Henriques, J. Mourão and R. Picken [37]

Electroweak Physics and the Early Universe, Sintra, March 1994.

Orgs. Jorge C. Romão and Filipe Freire [38]

Non-Sleeping Universe Conference, Porto, November 1997.

Orgs. M. T. V. Lago and A. Blanchard [39]

Cosmology 2000, Lisbon, July 2000.

Orgs. M. C. Bento, O. Bertolami, A. B. Henriques and L. Teodoro

(<http://alfa.ist.utl.pt/bento/cosmo2000/cosmo.html>)

JENAN 2002 The Unsolved Universe: Challenges for the Future, Porto, September 2002.

(<http://www.sp-astronomia.pt/jenam2002/>)

The Quest for Cosmological Scalar Fields, Porto, July 2004.

(<http://www.fc.up.pt/pessoas/luis.beca/>)

School on Superstrings: New Trends in String Theory, Lisbon and Porto (1998, 2001, 2004).

Orgs. M. C. Bento, O. Bertolami, M. Costa, C. Herdeiro, J. Mourão, J. Pimentel and R. Schiappa

(<http://www.math.ist.utl.pt/strings/MTST2/>)

New Worlds in Astroparticle Physics, Faro (1996, 1998, 2000, 2002, 2005).

Orgs. J. Dias de Deus, A. Mourão, M. Pimenta, R. Potting and P. Sá

(<http://www.ualg.pt/fct/fisica/centra/astroparticle2005/a2005.html>)

### 3 The Future: Aspirations and Challenges

It is clear that cosmology has undergone an impressive development in Portugal in the first two decades of its history. However, despite this growth, there are serious concerns about the will of the institutions to keep up this positive trend in the future. The reasons are manifold, the most noticeable being:

- i) The university and the national laboratory system are still too opaque and have shown no clear signs that they are able and willing to absorb the young generation via fresh job positions and to create intellectually stimulating research spaces. In our opinion, the creation of stable positions for the young generation of researchers should be a top priority. Furthermore, several structural changes must be promoted so that careers are regulated by criteria of excellence and not by “Monte Carlo” methods ... That is to say, a radical change is urgently needed in the criteria of access and promotion for the university and research positions. Emphasis on creativity, innovation and mobility within institutions must be implemented as soon as possible so as to avoid a brain drain problem.
- ii) It is unclear whether the cosmology community will be able to rely on a regular and continuous support from the existing institutions (Ministério da Ciência, Tecnologia e Ensino Superior, Fundação para a Ciência e a Tecnologia and so on) given budgetary difficulties arising from restrictions by the European Monetary Fund, economic performance and so on. Furthermore, financial support is often incipient and too conditioned by changes of political nature.

We think that it is uncontroversial to state that it would be beneficial for the community to count on with a national laboratory devoted to Astronomy, Astrophysics and Cosmology given that there are no astronomy departments in the country. Of course, an institution of this nature should concentrate various competences such as, for instance, the ones associated with data storage, computational facilities and hardware support. A national laboratory would also help to strengthen the spirit of

the community as well as the ties with the existing financing institutions and could open up new forms of collaboration with private institutions and individuals. Finally, we feel that it is important to stress that, despite all the difficulties, the cosmology community in Portugal can realistically aim to establish its position in the league of the top 5 strongest in Europe. The assessment of the first 20 years of development indicates that this is quite within reach, however this goal can only be achieved if we can ensure, through our concerted action, the long term success of the portuguese cosmology community and if conditions are created for the settling and blooming within our institutions of the young generation of researchers. It would be a waste if the country could not make proper use of the existing talents.

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